AN ASSESSMENT OF WATER QUALITY IN GULL LAKE (1999-2000)

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SUMMARY

In 1998, concerned residents requested Alberta Environment (AENV) conduct a diagnostic study to identify key nutrient sources in the Gull Lake watershed and to determine whether lake water quality had changed since sampling began 30 years ago. The Gull Lake Water Quality Management Society, which was established in 1998, co-operated with AENV in the investigation.

This report presents a summary of current water quality conditions in the lake and includes a preliminary assessment of water quality in the main inflowing tributaries.

Levels of total phosphorus and chlorophyll-*a* in Gull Lake have not increased significantly since monitoring began thirty years ago, nor has the general mineral content of the lake changed.

The four large streams that enter the southeast side of the lake represent 70% of the external watershed supply of phosphorus, based on 1999 data. Concentrations in these streams are very high compared with streams elsewhere in the province. The high concentrations could increase the growth of aquatic vegetation along the shoreline in that area, even though the lake, as a whole, is not yet affected. The quality of water diverted from the Blindman River will be assessed during future pumping episodes.

Although certain pesticides were present in all of the monitored streams, levels were well below Canadian Environmental Quality Guidelines for the protection of aquatic life. Fecal coliform bacteria counts were very high in streams, and some exceeded guideline levels for contact recreation.

Alberta Environment will work with stakeholders to determine whether a watershed-based management approach to the protection of the lake is required. This plan could encompass such factors as the need for additional stream monitoring, and identifying controllable sources of phosphorus throughout the watershed (e.g., domestic sewage). The quantity of water entering the lake via surface run off could also be measured with continuous water level recorders on several of the largest streams (e.g., North, Beaver, Wilson, Sailing Club) to improve the confidence in phosphorus loading estimates. Sources of phosphorus in these largest streams, particularly agricultural, could also be assessed further.

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We thank Rick Pickering, John Willis (AENV) and all other technologists who assisted with the inflow stream sampling.

Volunteers from the Gull Lake Water Quality Management Society surveyed the shoreline and identified potential sampling sites in 1998. We thank them for supplying insightful information about the watershed and for collecting lake samples during 1999, 2000 and 2001, as well as storm event samples from streams.

Bridgette Halbig (AENV) provided technical assistance by preparing maps, graphs and formatting the report. Jim Ames delineated watershed sub-basin boundaries.

Dave Trew (AENV) critically reviewed the draft report.

1.0 INTRODUCTION

Gull Lake is a popular and heavily used recreational lake located about 20 km northwest of Red Deer, Alberta. The lake and its watershed straddle the boundary between the Counties of Ponoka and Lacombe. Over the years it has displayed fairly clear water during the summer months. However, in recent years, lake users have noticed an increase in the growth of aquatic vegetation along beaches, and are concerned that water quality may be deteriorating.

In 1998, concerned residents approached Alberta Environment (AENV) to conduct a diagnostic study to identify key nutrient sources and to determine whether lake water quality had changed since sampling began 30 years ago. The Gull Lake Water Quality Management Society, which was established in 1998, co-operated with AENV in this investigation.

The long-term decline in water levels has been another issue at Gull Lake. In the late 1960s, a study was conducted to determine what could be done to stabilize the water level (Bailey 1970). A diversion from the nearby Blindman River was proposed, and pumping began in 1976. Pumping continues, but only when lake levels fall below a designated "trigger" elevation (898.89 m above sea level) and when minimum in-stream flows can be ensured in the Blindman.

Gull Lake has been sampled periodically over the past thirty years during a number of different investigations. In October 1972, the University of Alberta initiated a study of several lakes around the province, including Gull Lake. During 1977-78, Alberta Environment conducted a two-year study to assess the effects of the Blindman River diversion (Mitchell 1981). Between 1983 and 1998, provincial park staff and Alberta Environment collected monthly samples during the summers of most years. Since 1999, volunteers with the Gull Lake Water Quality Management Society (under the direction of the Alberta Lake Management Society) have conducted sampling activities. Finally, Alberta Environment and volunteers collected inflow stream samples during runoff periods in 1999-2000 as part of this diagnostic study.

The purpose of the following report is to summarize information from these studies and to address the following questions:

- Has the amount of algae in Gull Lake changed since sampling began in 1972?
- What are the major sources and quantities of phosphorus entering the lake?
- Are levels of pesticides and fecal bacteria entering the lake a concern?
- What further studies will be needed to understand water quality in the lake and how to protect it?

2.0 METHODS

Various sampling methods have been used in previous studies on Gull Lake. In general, however, samples were collected either by going to the deepest areas of the lake and collecting discrete samples at depths of 1 m and near the bottom (1972-1974, 1977-79), or by collecting vertically integrated samples at 15-20 locations with a sampling tube (since 1983). The "tube" samples, which are taken only to the depth that light penetrated on the sampling day (called the euphotic zone), are then combined into one sampling jug. This gives a "composite" picture of the lake as a whole.

Nutrients (phosphorus and nitrogen), general water chemistry, dissolved oxygen, pH, temperature and chlorophyll-*a* were analyzed on most samples, and a Secchi disk was used to measure transparency or clarity of the water. Chlorophyll-*a* is a photosynthetic pigment found in planktonic algae. It can be chemically extracted from a raw water sample and provides a simple estimate of the amount of algae in the lake on the sampling day.

Samples were collected frequently from the larger streams entering the lake (Figure 1) during spring 1999 (a high runoff period) and spring 2000 (a moderate runoff period). As well, stream samples were collected in summer 1999 after a large rainstorm. These samples were analyzed for nutrients, suspended solids, fecal coliform bacteria, total organic carbon and field variables (temperature, pH, dissolved oxygen and conductivity). Flow rate (in cubic metres per second) was measured each time a sample was collected. Samples were also collected from the Blindman River, near the pumphouse, although no pumping occurred during the two study years. Also in 2000, pesticide samples were collected from the larger streams during spring and summer.

Phosphorus loading estimates to Gull Lake were first derived in 1980 (Mitchell 1981). The supply of total phosphorus (TP) entering the lake from the land surface was estimated with "export coefficients" – the amount of phosphorus exported from a hectare of land per year. These coefficients were derived from a detailed study on Baptiste Lake in 1978 (Trew et al. 1987). Using air photos and topographic maps, the amount of cleared land, forested land and "urban" land was estimated for the Gull Lake watershed, and the appropriate export coefficient was applied to that amount of land. For example, it was estimated that the amount of cleared land in the watershed was about 15,000 hectares. The (TP) export coefficient used for this land use was 0.5 kg/ha/yr, which gives a total annual loading estimate from cleared land of approximately 7600 kg.

Phosphorus loads contained in sewage potentially entering the lake from cottages and camps were calculated using a per-capita estimate of 0.93 kg of phosphorus/year (also from the Baptiste Lake study). User-density information (required to calculate theoretical sewage loads) were supplied by regional planning commissions and provincial park staff. It was assumed that all sewage generated from cottages and camps around the lakeshore eventually went into the lake (i.e., the worst case scenario). The actual amount is undoubtedly smaller, but there was no reliable way to estimate the true amount. An atmospheric deposition coefficient was used to estimate the amount of phosphorus falling onto the lake's surface in rain and dust.

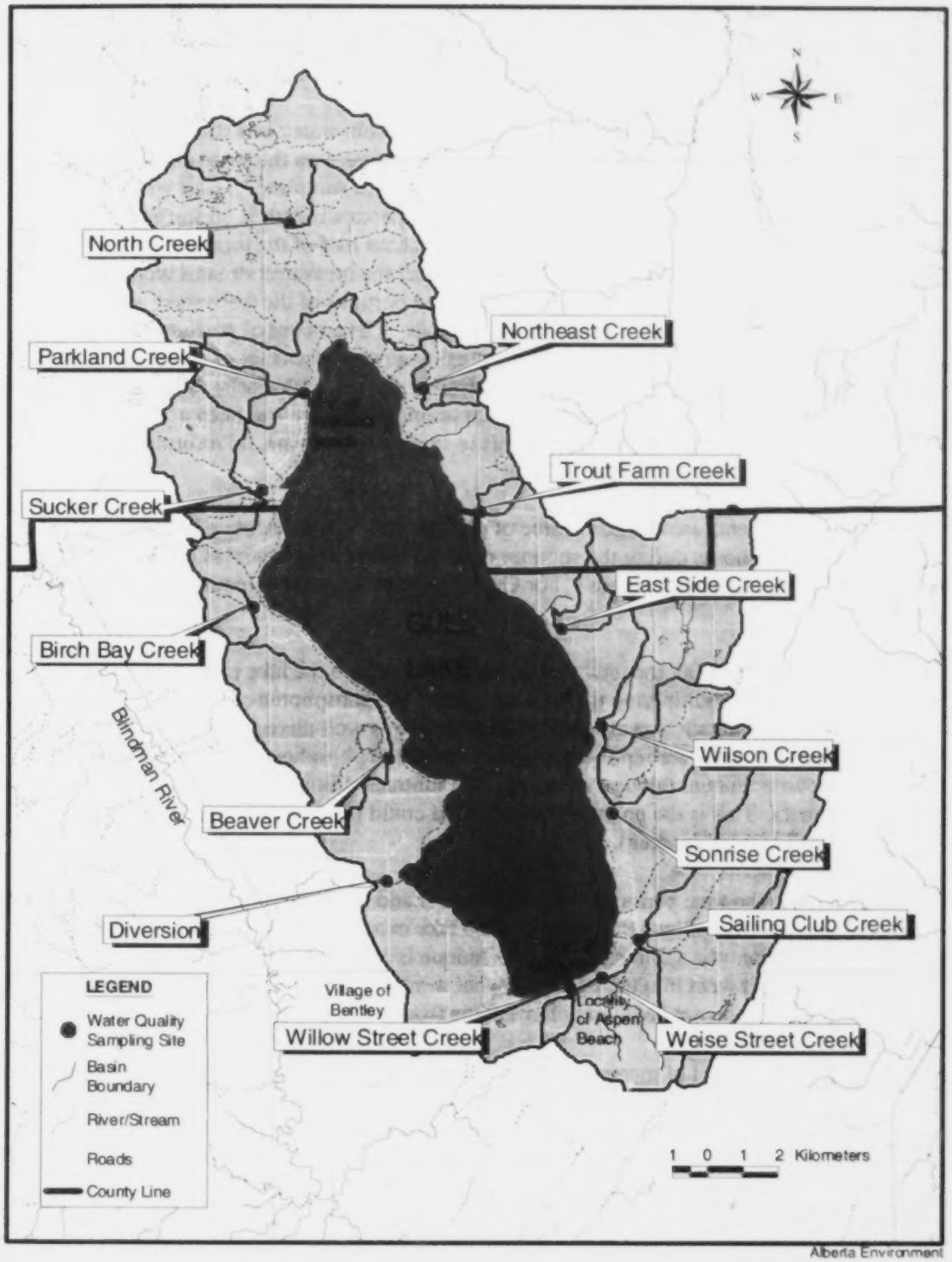

Figure 1 Location of water quality sampling sites on streams in the Gull Lake study area, 1999-2000

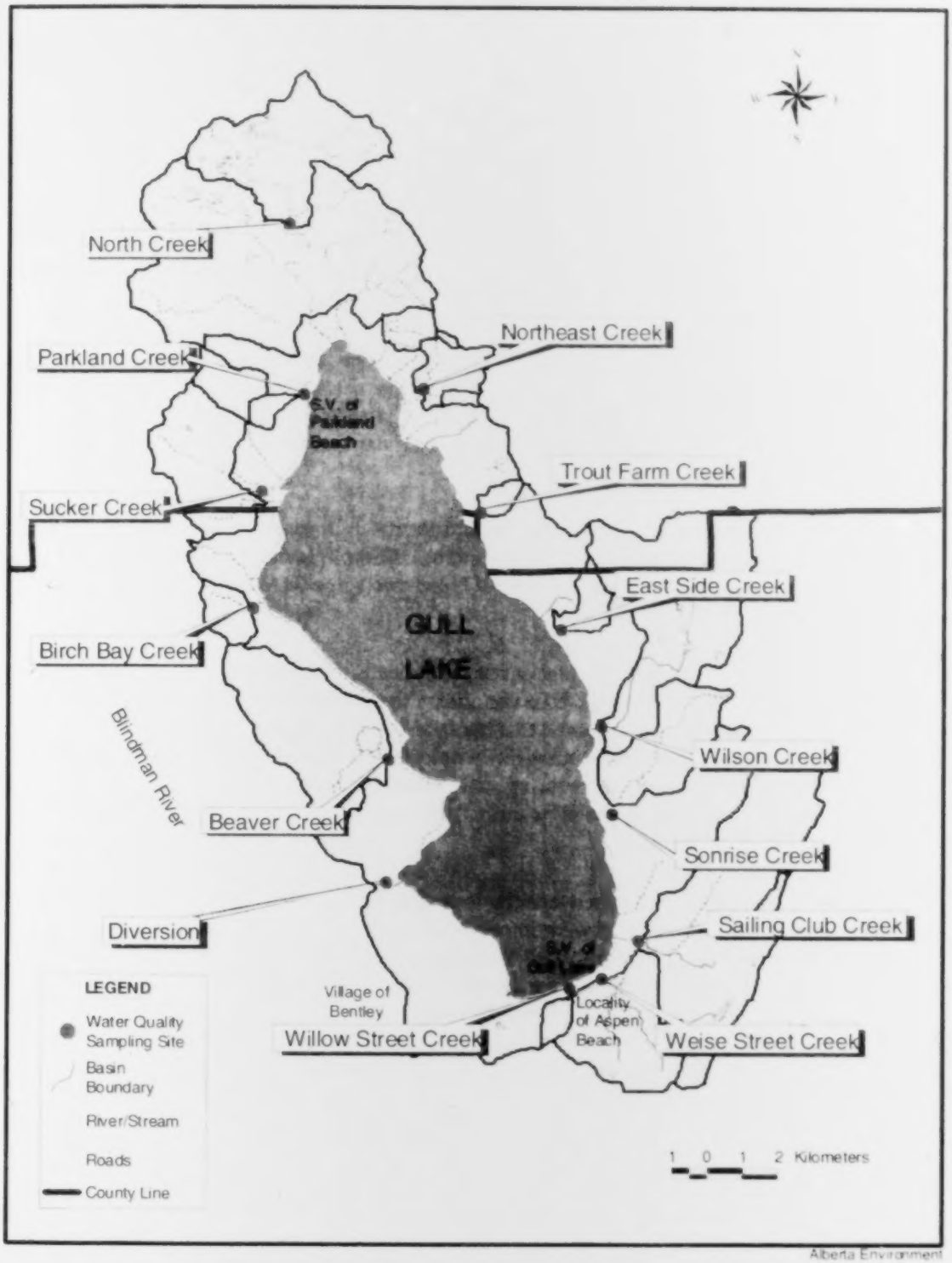

Figure 1 Location of water quality sampling sites on streams in the Gull Lake study area, 1999-2000

The more recent phosphorus loading estimates for Gull Lake (published in the *Atlas of Alberta Lakes, 1990*) are based on updated studies from other lakes in Alberta.

For the present assessment, phosphorus concentration data from watershed streams were multiplied by the instantaneous flow measured in the same stream on the same date. This results in a *load*, or quantity of phosphorus in the stream at the time of sampling. These were extrapolated over time for the full runoff periods (usually about a month in spring and two weeks in summer). The monitored streams only accounted for about half of the total drainage area of the watershed (Figure 1). Therefore, the TP loads from all the measured streams were proportionally extrapolated to the remaining unmeasured portions of the watershed. It was also assumed that these creeks did not flow during dry periods. The amount of phosphorus entering the lake in precipitation and dustfall was estimated using a more recent set of atmospheric deposition coefficients derived from a study on Narrow Lake near Athabasca (Shaw et al. 1989). For sewage, the original estimate was updated by assuming that there had been a 25% increase in lakeshore development since 1980. Although this is strictly an estimate, no information on development over the past 20 years is available.

The lake bottom sediments are a major source of phosphorus in many Alberta lakes, and typically release phosphorus during the summer months. This phenomenon is often termed "internal loading" or "sediment release". For Gull Lake, two steps were required to estimate this amount:

- For 1999 and 2000, the total amount of phosphorus in the lake each month was calculated by multiplying the lake volume by the phosphorus concentration in the lake at the time. It was assumed that the lake was well mixed vertically, and that the "tube" samples were representative of whole-lake phosphorus concentrations. Then the lowest amount (always in spring) was subtracted from the highest amount (in late summer). This is the potential quantity that could have come from the bottom (the "gross" internal loading).

- Then, for the time period between the lowest and the highest amounts in the lake, the amount of phosphorus that went into the lake externally from the watershed and precipitation was subtracted. This technique is called a "mass balance". If one knows what went into the lake (and what went out, if there were an outflow), the remaining increase could only have come from the bottom of the lake.

- The total amount of increase could be made up of sewage inputs, groundwater inputs and the amount from the sediments themselves. To avoid "double counting", the amount estimated from sewage was subtracted from the internal load to provide an estimate of the "net" internal loading.

3.0 RESULTS AND DISCUSSION

3.1 Physical and Hydrological Characteristics of Gull Lake

Physical characteristics of Gull Lake are presented in Table 1 and a map of the lake showing stream watersheds is presented in Figure 1. The hydrologic data in Table 1 represent conditions up to 1989, and are taken from the Atlas of Alberta Lakes (Mitchell and Prepas 1990).

The drainage area to lake surface area ratio is small (approximately 2.5 to 1), and the lake is very shallow for its size. Note that the average annual inflow volume from the watershed and from precipitation onto the lake's surface is slightly lower than the average amount of water lost from evaporation. Thus, a series of dry years typically result in declining water levels (Figure 2). The diversion was designed to make up this deficiency, although it has operated in only 13 of the 25 years since it was constructed in 1976. When pumping occurs, the diversion inflow represents only 1% of the lake volume. The target elevation is 899.16 m. above sea level.

Table 1 Physical Characteristics of Gull Lake

Elevation, m [a]	899.23
Surface Area, km^2 [a]	80.6
Volume, million m^3 [a]	437
Maximum Depth, m [a]	8.0
Average Depth, m [a]	5.4
*Average Annual Inflow, million m^3	14.3
**Diversion Inflow, million m^3	5.4
Average Annual Precipitation, million m^3	37.2
Average Annual Evaporation, million m^3	51.6
Water Residence Time, years	>100
Drainage Basin Area (excluding lake), km^2	206

[a] *on date of sounding, August 1961*
* *Excluding diversion, but including (unmeasured) groundwater inflow.*
** *Average of years when pumping occurred.*

Long-term runoff estimates were derived to place the measured stream flow data for 1999/2000 in perspective. A number of regional streamflow survey stations were examined to determine the most representative station to use and the Water Survey of Canada station on nearby Lloyd Creek (05CC009) was selected. Monthly inflows to Gull Lake using Lloyd Creek data were derived for each year since 1965 (Figure 3). Inflows for both 1999 and 2000 were above average (and median). Inflows for 1999 ranked among the top 25% of inflows for all years. In 2001, however, inflows were the lowest recorded since 1965.

Figure 2 Historic monthly mean lake levels for Gull Lake at Aspen Beach

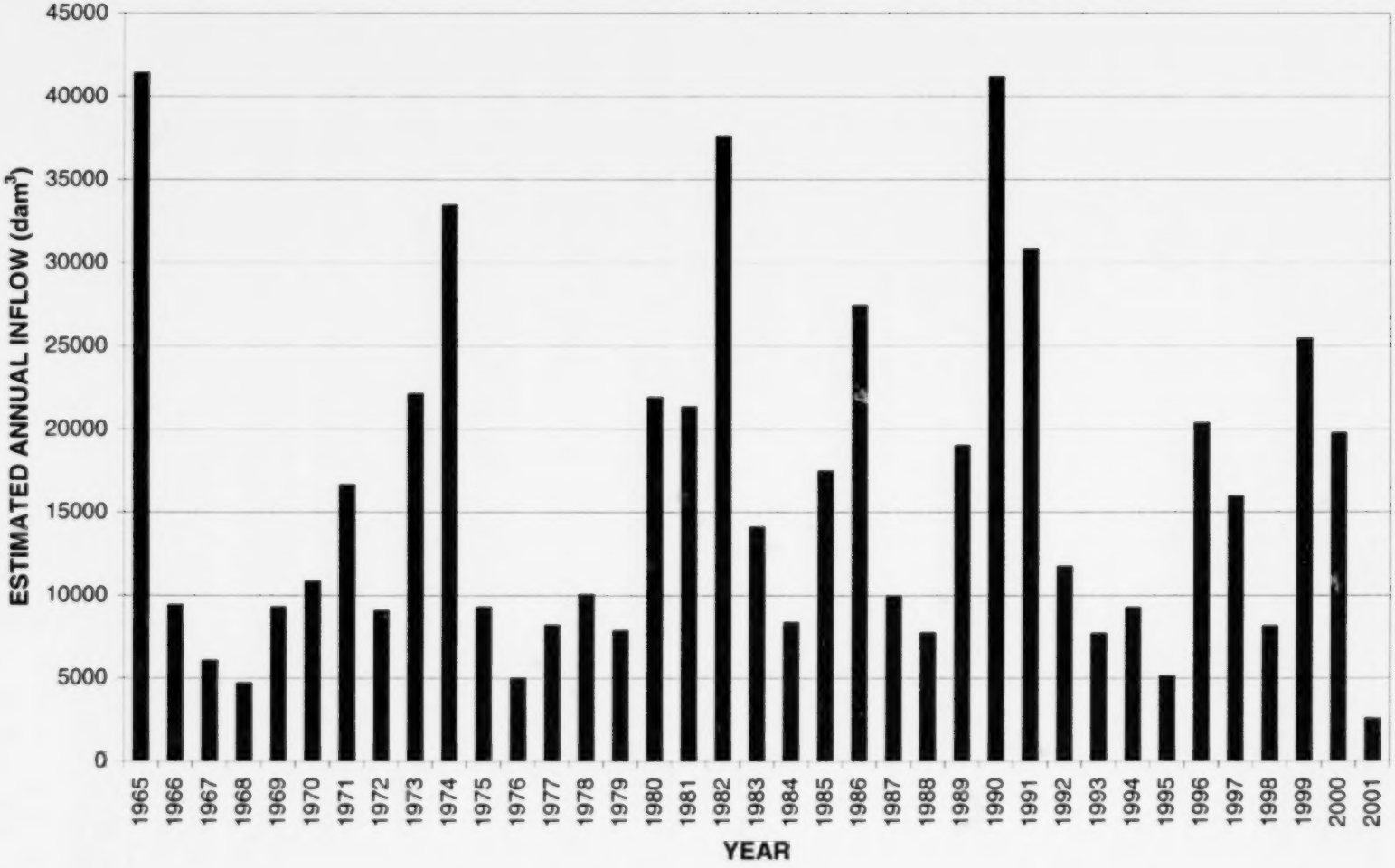

Figure 3 Total estimated annual inflows to Gull Lake, 1965 to 2001

The derived inflow volumes for spring runoff in 1999 were about 2 ½ times larger than was indicated by the measured tributary data. There can be large errors associated with the extrapolation of instantaneous measured flows to daily flows, because of diurnal variability in thaw and flow rates which occur during spring runoff. The significance of the hydrological data will be discussed further in Section 3.4.

An updated mean annual water balance was also derived to determine the approximate inflows required to sustain the lake level. This water balance indicated that on average, about 16,000,000 m^3 (16,000 dam^3) of inflow would be required to maintain the lake at a constant volume (Douglas 2001).

3.2 General Chemical Characteristics

Average concentrations of major ions and related variables are presented in Table 2. Gull Lake is considered to be slightly saline, based on its TDS levels. Total dissolved solids concentrations observed during 1973-1979 were statistically compared with more recent data (1988-2001). It was noted that TDS had increased slightly during this interval (1973-1979 average = 757 mg/L; 1988-2001 average = 767 mg/L)[1]. Even during recent years, however, the levels of total dissolved solids and major ions are within the optimum range for the protection of aquatic life.

Table 2 Average summer concentrations of major ions and related variables for Gull Lake, 1983-2001
(Number of samples = 46)

pH (range)	8.8 – 9.2
Specific Conductance, uS/cm	1199
Total Dissolved Solids (calc.), mg/L	758
Iron, mg/L	0.03
Total Hardness, mg/L	294
Magnesium, mg/L	65.0
Calcium, mg/L	10.6
Sodium, mg/L	194
Potassium, mg/L	18.9
Sulphate, mg/L	76.5
Chloride, mg/L	4.5
Silica, mg/L	6.6
Total Alkalinity, mg/L as CaCO3	646
Bicarbonate, mg/L	637
Carbonate, mg/L	80

[1] Mann-Whitney test, $P<0.003$, n=97,30.

3.3 Nutrients and Algae

Algae are the microscopic, free-floating plants that tint the water green in summer. The growth and biomass of algae are usually proportional to nutrient concentrations. When the supply of nutrients – phosphorus and nitrogen – to a lake is high, a "bloom" of algae can result, and the water may look like "pea soup". In Gull Lake, however, dense growths of algae rarely occur.

The amount of algae in the lake is assessed by analyzing the *chlorophyll* content of a water sample. Chlorophyll is the photosynthetic pigment found in all green plants, and one type, chlorophyll-*a*, is almost universally found in algae. The amount of chlorophyll-*a* in a lake water sample gives an excellent indication of how much algae was in the lake on the day of sampling.

The levels of phosphorus and chlorophyll-*a* measured in Gull Lake during 1999 and 2000 are illustrated in Figure 4. Note that when the level of chlorophyll-*a* is lowest, the transparency of the water is highest (June of both years). As well, levels of chlorophyll-*a* and phosphorus tend to be highest in mid to late summer. This is a typical seasonal pattern observed in many shallow lakes in Alberta.

Figure 5 illustrates average phosphorus, chlorophyll-*a* and Secchi transparency data for the last 19 years. Based on statistical comparisons between early (1978-1989) and later (1990-2001) data [2]), there appears to be no evidence that the amount of algae or phosphorus has increased. Furthermore, recent concentrations of chlorophyll-*a* are similar to those observed in 1972-1974 (8.2 mg/m^3) and 1978-79 (8.1 mg/m^3). Gull Lake shows no decline in water quality based on these data.

The overall average concentrations of chlorophyll-*a* in Gull Lake (Table 3) are compared with those of other Alberta lakes in Figure 6. The average summer chlorophyll value indicates that the lake is on the borderline between *mesotrophic* (moderately productive) and *eutrophic* (highly productive). The average summer phosphorus level, however, suggests that the lake is eutrophic. The higher salinity in Gull Lake may suppress algal growth compared with the phosphorus supply available. This pattern of reduced algal growth has been observed in other saline Alberta lakes (Bierhuzen and Prepas 1985).

Table 3 Average Secchi transparency and concentrations of phosphorus, nitrogen, and chlorophyll-*a* in Gull Lake, May–September, 1983–2001

Secchi Depth Transparency, m	2.5
Total Phosphorus, mg/m^3	45.1
Total Nitrogen, mg/m^3	1550
Chlorophyll-*a*, mg/m^3	8.4

[2] Mann-Whitney test, $P>0.2$, n=29,48.

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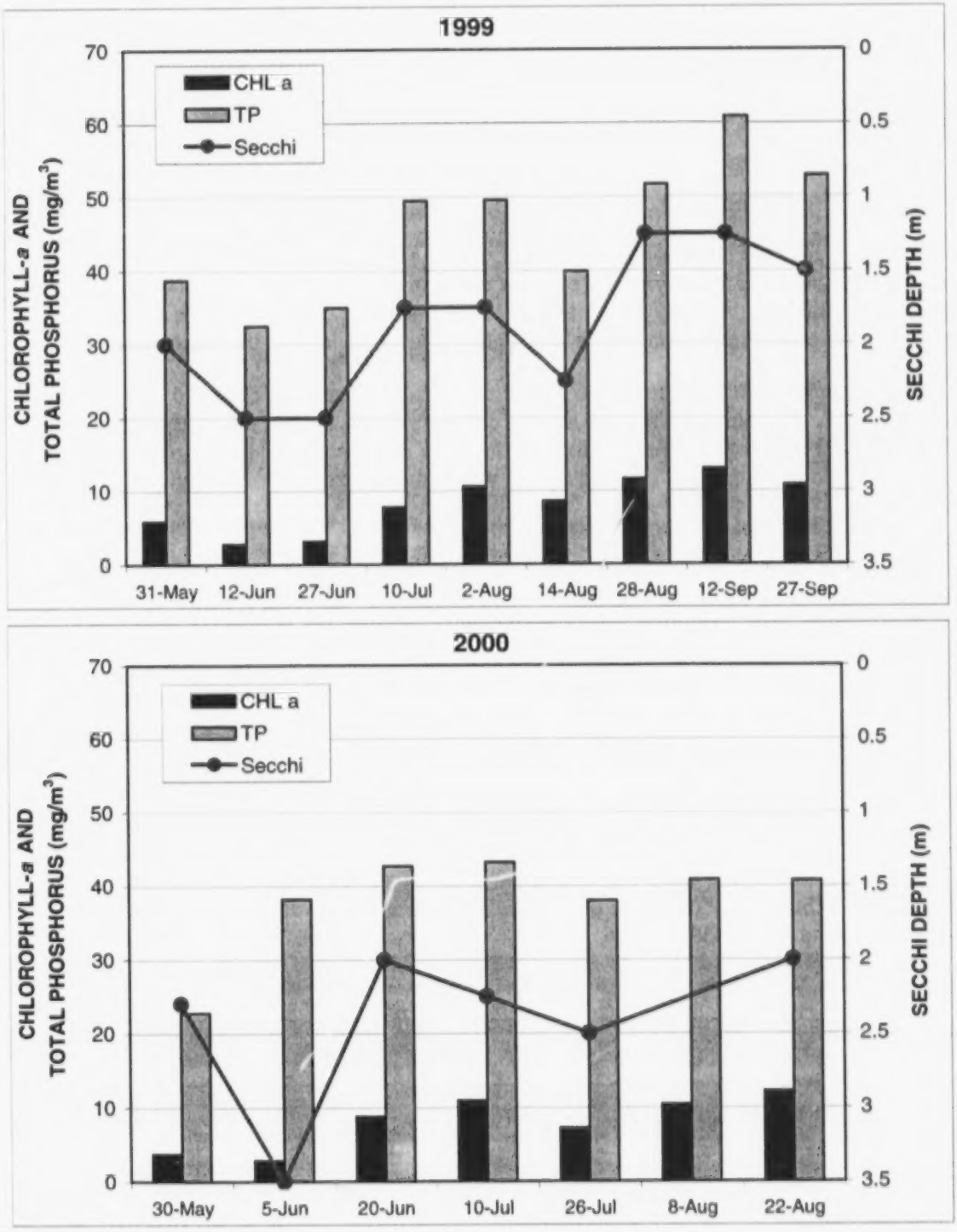

Figure 4 Seasonal changes in Secchi transparency and concentration of phosphorus and chlorophyll-*a* in Gull Lake in 1999 – 2000

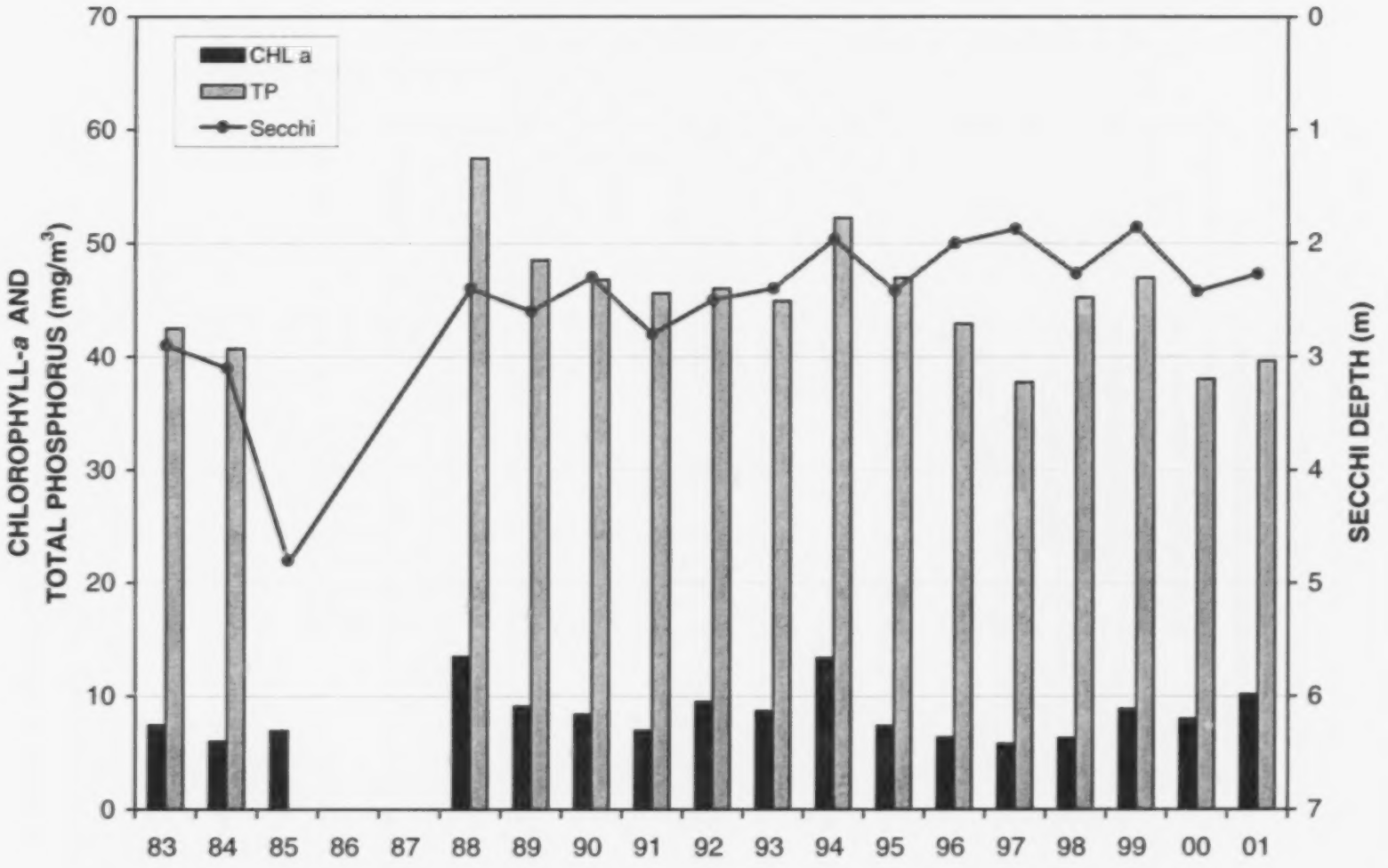

Figure 5 Average open water Secchi transparency and levels of phosphorus and chlorophyll-*a* in Gull Lake, 1983-2001

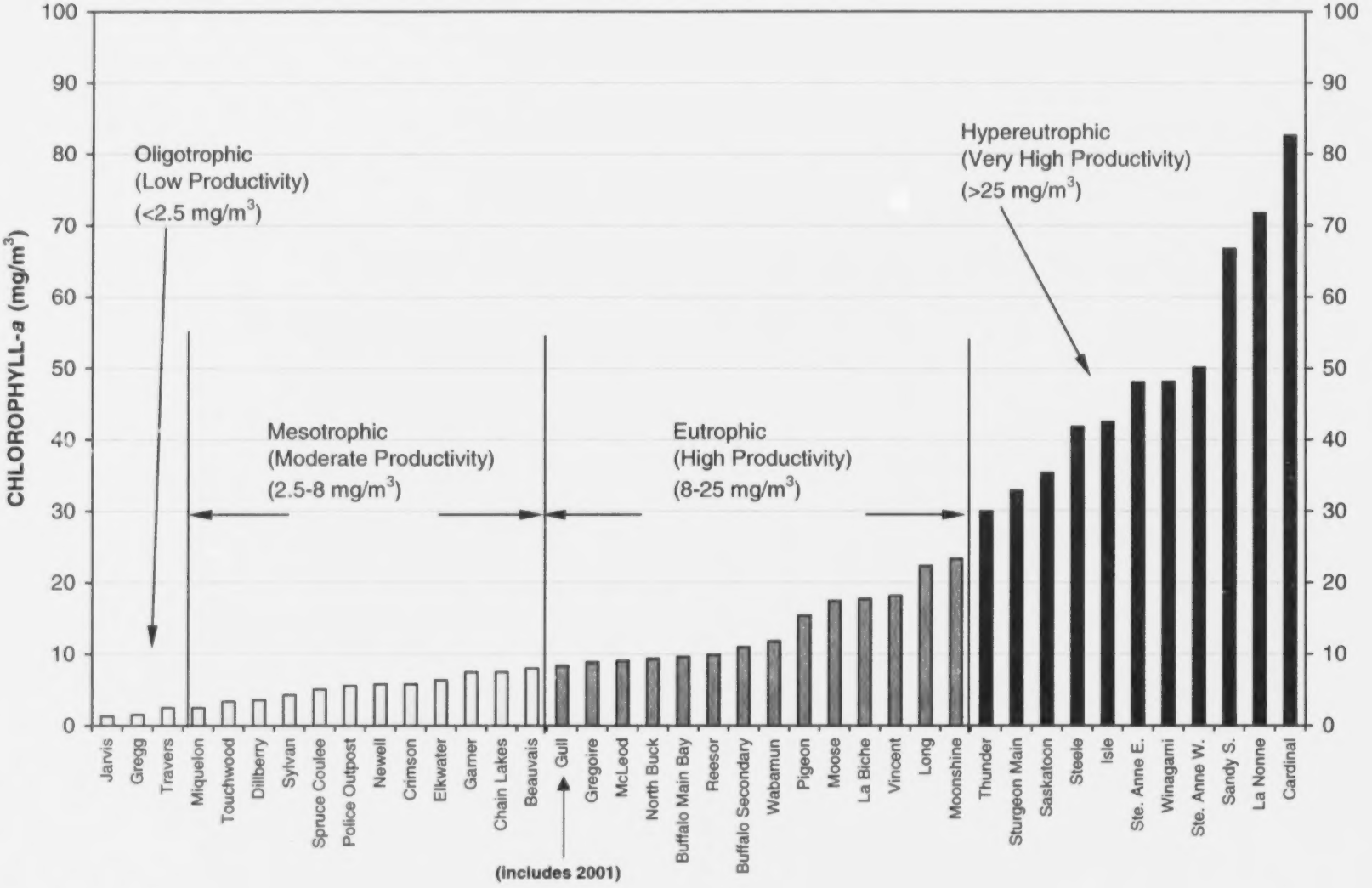

Figure 6 Trophic status based on average chlorophyll-*a* levels in Gull Lake and other Alberta lakes

Many lake users are concerned about the perceived increase in "weeds" in the lake. These are the large submergent or emergent plants that are more correctly called "macrophytes". However, it is very difficult to accurately measure the amount of shoreline aquatic vegetation in a lake, much less to assess whether it has increased. There are no recent macrophyte biomass data for Gull Lake.

3.4 Phosphorus Loading Estimates for Gull Lake

The phosphorus supply (or loads) to a lake usually governs how much aquatic plant growth the lake can support. Algae will grow in proportion to the phosphorus supply, so when large amounts of phosphorus enter a lake, green scummy water may result. Lake scientists generally agree that the key to recreational water quality in most lakes is phosphorus. If the phosphorus supply should increase, the amount of algae in the lake will also likely increase. The relationship between phosphorus and macrophyte populations is not as clear, because these plants take their nutrients from the bottom sediments, which may accumulate nutrients for many years.

The original (1980 and 1989) phosphorus loading estimates for Gull Lake are presented in Table 4. These early loading estimates suggested that the external supply (from the watershed) represents the major phosphorus source, although internal loading was not estimated.

Table 4 Original estimates of phosphorus supply to Gull Lake, in kilograms/year

	1980*	% of Total External	1989**	% of Total External
Watershed	8115	67%	3568	52%
Precipitation and Dustfall	2432	20%	1760	26%
Sewage***	876	7%	876	13%
Diversion	769	6%	615	9%
Total External	12192		6819	

* Mitchell 1981

** Alberta Environment 1989

***Worst case - assumes that all phosphorus contained in sewage derived from shoreline development enters the lake

The measured phosphorus loadings from the 1999-2000 study are presented in Table 5. Note that the new estimates are for the spring/early summer period only, whereas the historic estimates are based on flow regimes more typical of the full open water season. The inflow streams to Gull Lake were not active during late summer and fall of 1999 and 2000.

The "measured" loadings from the watershed are similar to those of historic supply estimates. The phosphorus supply from the watershed for 2000 is considerably lower than for 1999, because the streams ran at lower flow rates and for a shorter time. The estimated phosphorus supply from "net" internal loading is somewhat higher than that from the watershed. During

Table 5 Summary of measured inputs of total phosphorus in kilograms, March-September

	1999	% of Total External	2000	% of Total External
Watershed	9200	78%	2000	43%
Precipitation and Dustfall	1600	14%	1600	35%
Sewage*	1000	8%	1000	22%
Diversion**	0	0%	0	0%
Total External Loading	11800		4600	
Internal Loading	8700		7500	

* Worst case. Assumes number of cottages has increased by 25%

** Diversion flows only occasionally, i.e., 13 years out of the past 25. (2056 kg estimated to enter lake during diversion years)

summer, internal loading is often the major source of phosphorus in shallow Alberta lakes such as Gull.

Note that the potential amount from sewage is a small percentage of the total supply in all estimates except for 2000. (Again note: the supply from cottages and camps around the lakeshore assumes a worst-case situation; it has not been measured.)

Although water was not diverted from the Blindman River in 1999 or 2000, the potential phosphorus supply from this source is relatively large (1660 kg). This value is based on the average volume of water pumped during recent diversion years and average phosphorus concentrations measured in the Blindman River in 1999 and 2000. Note that it is higher than those in Table 4, mainly because phosphorus concentrations measured in the river were higher than those measured in the early years. The quality of water diverted from the Blindman River will be assessed during future pumping episodes.

The 1999 TP loads and flow-weighted mean concentrations for individual streams are presented in Figure 7. Trout Farm Creek and Northeast Creek only flowed for a few days. Loads and concentrations were highest from the four creeks in the southeast part of the watershed (Weise Street, Sailing Club, Sonrise and Wilson - see Figure 1).

These flow-weighted mean concentrations are within the range for streams draining high agricultural intensity watersheds, as reported in the Canada-Alberta Environmentally Sustainable Agriculture study (Anderson et al. 1998). During spring runoff in 1999, these four creeks represented 70% of the total measured stream load. Concentrations were even higher in spring 2000, although loads were smaller because flows were reduced. Within the scope of this study, sources of phosphorus in these streams were not identified.

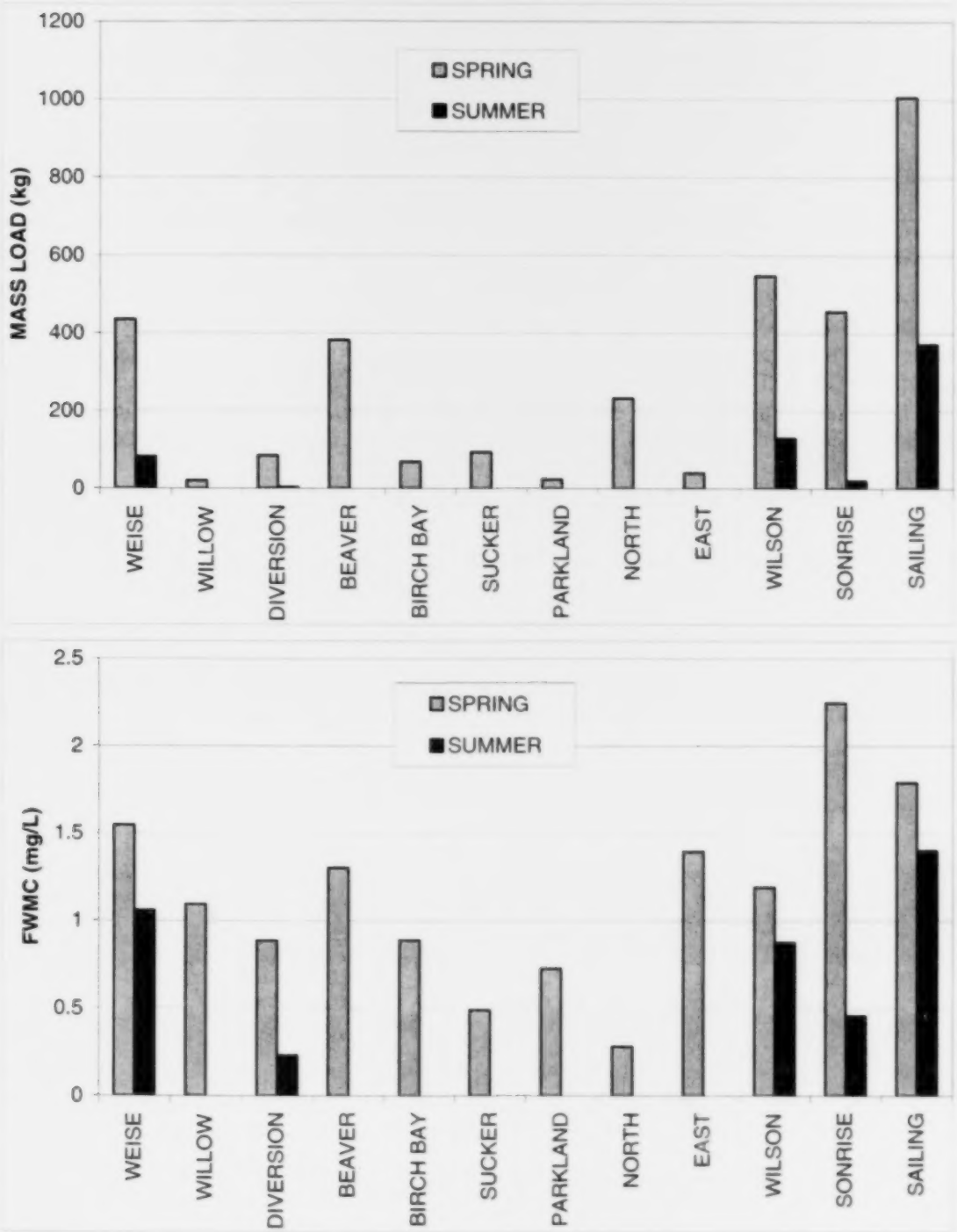

Figure 7 Mass loads and flow-weighted average concentrations of total phosphorus in Gull Lake streams monitored during 1999

3.5 Pesticides in Streams Draining to Gull Lake

Two to three pesticide samples were collected from streams in 2000. Table 6 summarizes the pesticide data collected in 2000 from the streams flowing into Gull Lake. Of the 40 pesticides analyzed, nine were detected in the streams. Most pesticides tested were not detected in most samples. A value that is reported as less than the detection limit ("L" = "less than") means that the analytical method used couldn't find it in the sample; if present it would be less than the detection limited stated. Values in bold represent the "reported" values.

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Table 6 Levels of pesticides in streams draining to Gull Lake, 2000
Only those pesticides with detectable levels in some streams are presented. A total of 40 pesticides were analyzed. All units in mg/m^3. (n = 2)

STREAM	DATE	2,4-D	Bromoxynil	Dicamba (Banvel)	Clopyralid (Lontrel)	MCPA	MCPP (Mecoprop)	Picloram (Tordon)	Trifluralin (Treflan)	Imazamethabenz-Methyl
Blindman River	28-Jun	**0.006**	L0.005	L0.02	L0.02	**0.007**	L0.005	L0.005	L0.005	L0.05
	10-Jul	L0.005	L0.005	L0.02	L0.02	L0.005	L0.005	L0.005	L0.005	L0.05
Wiese Street Creek	9-Jul	**0.04**	L0.005	L0.02	L0.02	**0.047**	L0.005	**0.18**	L0.005	L0.05
	15-Aug	**0.136**	L0.005	L0.02	**0.035**	**0.101**	**0.049**	**0.432**	L0.005	**0.048**
Sucker Creek	4-Jul	**0.211**	L0.005	L0.02	L0.02	**0.101**	L0.005	**0.263**	L0.005	L0.05
	9-Jul	**0.242**	L0.005	L0.02	L0.02	**0.022**	**0.052**	**1.36**	L0.005	L0.05
Parkland Creek	4-Jul	L0.005	L0.005	L0.02	L0.02	L0.005	L0.005	L0.005	L0.005	L0.05
	9-Jul	**0.123**	**0.006**	L0.02	L0.02	L0.005	**0.094**	**0.477**	L0.005	L0.05
	4-Jul	L0.005	L0.005	L0.02	L0.02	L0.005	L0.005	L0.005	L0.005	L0.05
	9-Jul	**0.143**	L0.005	L0.02	L0.02	**0.008**	**0.058**	L0.005	L0.005	L0.05
North Creek	31-Mar	L0.005	L0.005	L0.02	L0.02	L0.005	L0.005	**0.033**	L0.005	L0.05
	9-Jul	**0.016**	L0.005	L0.02	L0.02	L0.005	L0.005	**0.058**	L0.005	L0.05
Wilson Creek	31-Mar	**0.018**	L0.005	L0.02	**0.219**	**0.215**	L0.005	L0.005	L0.005	**0.868**
	2-Jul	**0.948**	L0.005	L0.02	**0.084**	**0.059**	**0.011**	L0.005	L0.005	**0.901**
	10-Jul	**0.077**	L0.005	**0.006**	**0.069**	**0.168**	L0.005	L0.005	L0.005	**0.082**
Sonrise Creek	31-Mar	**0.009**	L0.005	L0.02	**0.025**	L0.005	L0.005	L0.005	**0.002**	L0.05
	2-Jul	L0.005	**0.063**	L0.02	L0.02	L0.005	L0.005	L0.005	L0.005	L0.05
	10-Jul	L0.005	**2.68**	L0.02	L0.02	**0.02**	L0.005	L0.005	L0.005	**0.33**
Sailing Club Creek	31-Mar	**0.035**	L0.005	L0.02	**0.07**	**0.024**	L0.005	**0.039**	L0.005	**2.689**
	30-Jul	**0.194**	L0.005	**0.018**	**0.433**	**0.067**	**0.054**	**0.421**	L0.005	**0.243**
	15-Aug	**0.099**	L0.005	L0.02	**0.418**	**0.045**	**0.039**	**0.446**	L0.005	**0.39**
Guideline:		**4**	**5**	**10**	**n.g.**	**2.6**	**n.g.**	**29**	**0.20**	**n.g.**

L = less than analytical detection limit; n.g. = no guideline established

3.6 Fecal Coliform Bacteria in Streams Draining to Gull Lake

Fecal coliform bacteria are used as indicator organisms to demonstrate the potential presence of microbial pathogens derived from human and animal feces. These bacteria were measured in streams in July 1999 after a summer rainstorm (Table 7). The water quality guideline for contact recreation (less than 200 organisms per 100 mL of sample) is based on the geometric mean of at least five samples collected within a 30-day period. Only three streams met this sampling requirement, and none of these met the guideline for fecal coliform bacteria. It is apparent that levels in most of the other streams are also very high. This suggests that these streams are being contaminated by fecal material, either from livestock or human sources.

Table 7 Fecal coliform bacteria in streams draining to Gull Lake, 1999
(Units = organisms per 100 mL)

Date	Weise Street	Diversion Channel	Sucker	Parkland	North	East Side	Wilson	Sonrise	Sailing Club
6-Jul						10	570	90	250
8-Jul	200	9800				600	2800	490	20000
12-Jul	20				110		540	64	45
15-Jul	700	5300	1400	3000	1100		3600	210	15000
19-Jul	20				220		320	2400	73
Geometric Mean:	**87**	**7207**	**1400**	**3000**	**299**	**77**	**999**	**270**	**756**

Guideline for contact recreation: geometric mean for 5 samples collected over 30 day period: 200 counts per 100 mL

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Geometric Mean:	87	7207	1400	3000	299	77	999	270	756

Guideline for contact recreation: geometric mean for 5 samples collected over 30 day period: 200 counts per 100 mL

4.0 CONCLUSIONS

This report represents a preliminary assessment of water quality conditions in Gull Lake and its watershed.

Levels of total phosphorus and chlorophyll-*a* in Gull Lake have not increased since monitoring began. However, to protect water quality in the lake, it is important to determine the sources of phosphorus in the watershed and along the shoreline, and reduce quantities wherever possible.

The four larger streams that enter the southeast side of the lake represent 70% of the external watershed supply of phosphorus, based on 1999 data. Concentrations in these streams are very high, compared with streams elsewhere in the province. The high concentrations could increase the growth of aquatic vegetation along the shoreline in that area, even though the lake as a whole is not yet affected.

The quality of water diverted from the Blindman River will be assessed during future pumping episodes. Alberta Environment will also work with stakeholders to determine whether a watershed-based management approach to the protection of the lake is needed. This plan may encompass additional stream monitoring requirements, and further identification of controllable sources of phosphorus throughout the watershed (e.g., agricultural sources; domestic sewage disposal practices). The quantity of water entering the lake via surface run off could also be measured with continuous water level recorders of several of the largest streams (e.g., North, Beaver, Wilson, Sailing Club) to improve the confidence in stream loading estimates.

The updated phosphorus supply estimates suggest that the supply from the bottom sediments (including groundwater inputs) can amount to as much as the supply from the watershed, especially when watershed runoff is low.

Although certain pesticides were present in all of the monitored streams, levels were well below Canadian Environmental Quality Guidelines for the protection of aquatic life.

Fecal coliform bacteria counts were very high in streams, and some exceeded guideline levels for those that met the guideline requirements of a minimum of five samples collected within a 30-day period.

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